T2100206-v1

LIGO SURF 2021

Simulating Scattered Light For use in Training Beam Tracking Algorithm

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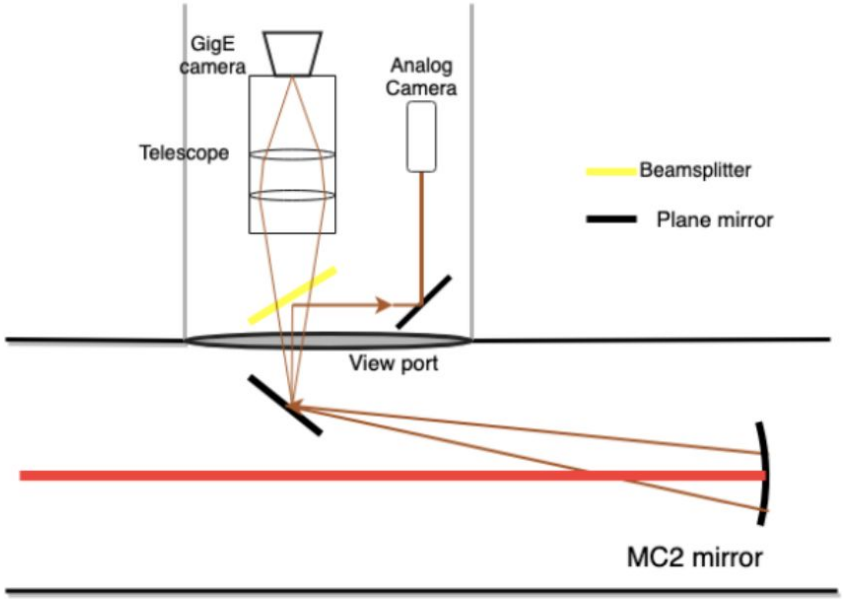
Tracking Beam Motion on aLIGO Mirrors

With cameras and computer vision

Using Supervised Learning Algorithm

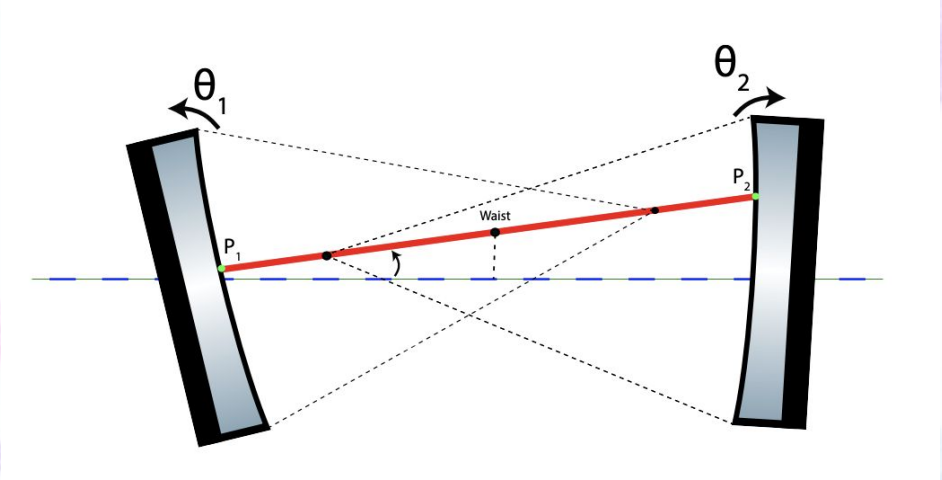
- Convolutional Neural Networks
- Need Labeled Data!
  - Annoying to gather
- Simulate it
  - Must be representative!



Kumar (2019)

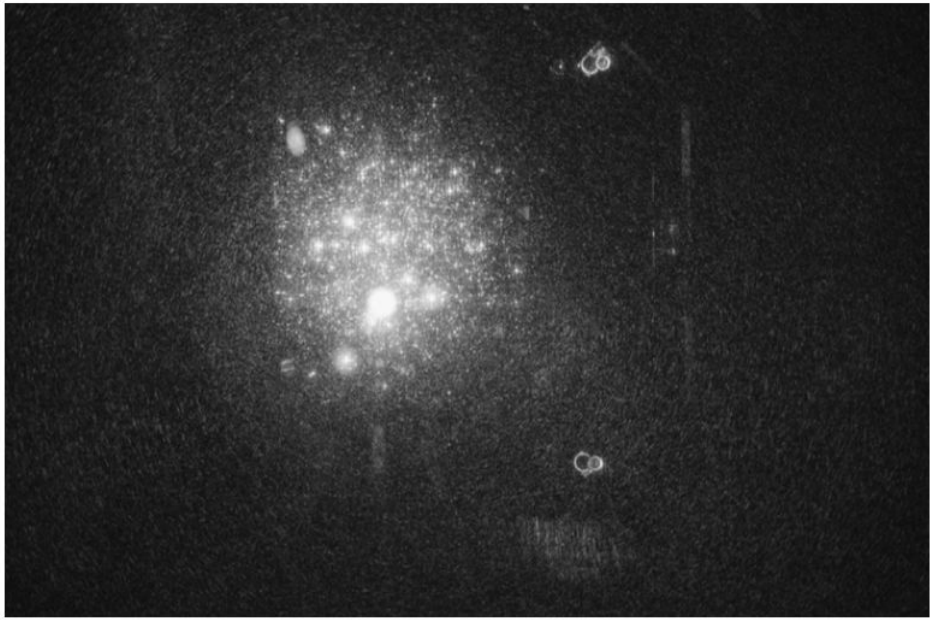
Why should we know where the beam is??

- It would be nice
- Calculate torque on optics due to radiation pressure
- Subtract angular noise (~10hz)??



Seymour (2017)

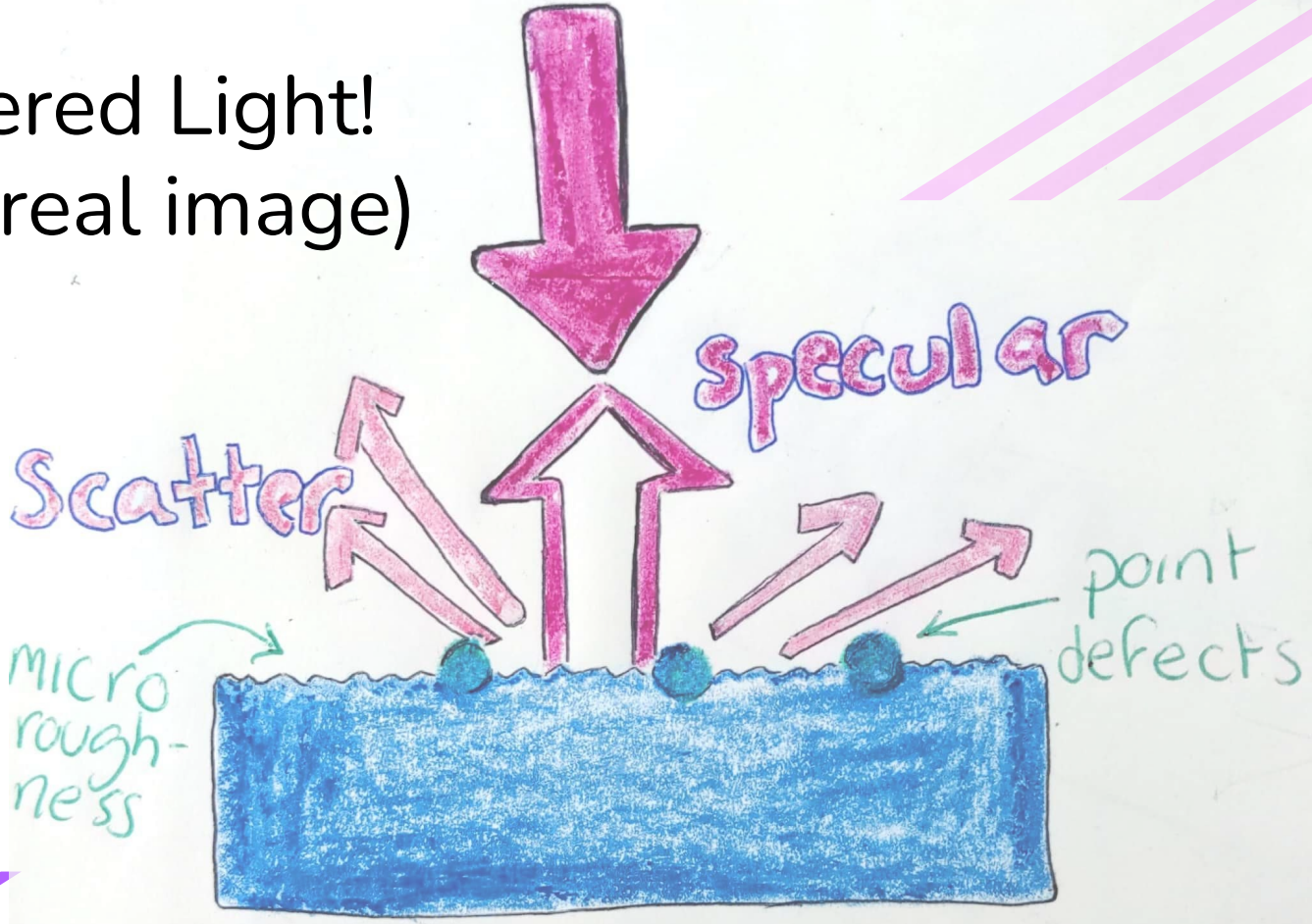
Components of a real image



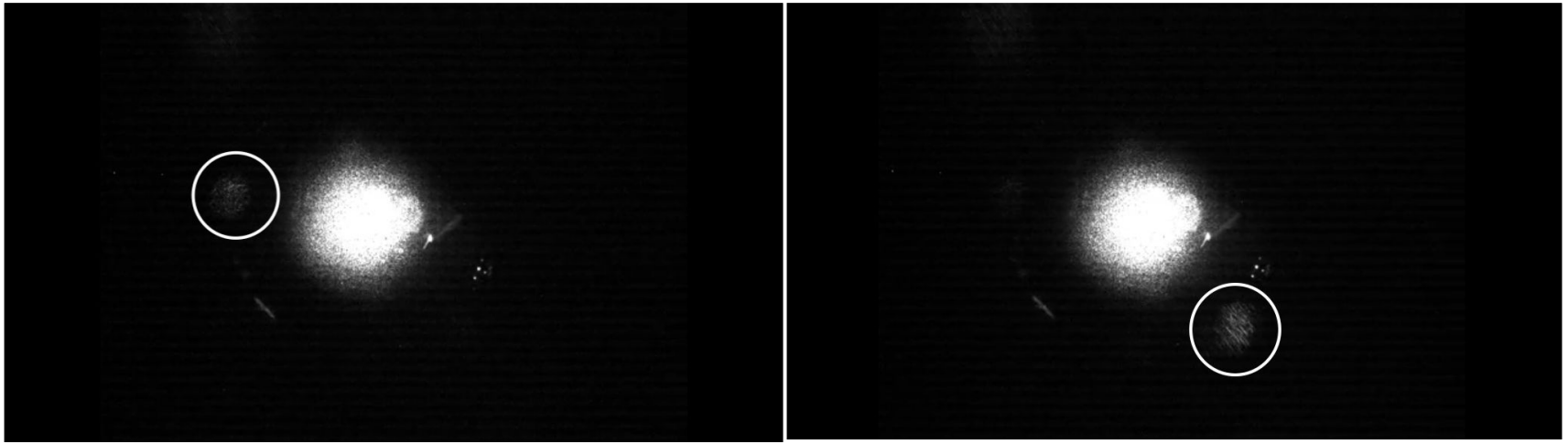
L.Glover et al. (2018)

- Point defects
- Microroughness
- Optical effects of camera/ lensing system
  - Glare
  - Near field vs. Far field
- Electronic effects
  - Saturation
  - Dark noise

Scattered Light!
(Not a real image)



What’s the point (scatterer)?

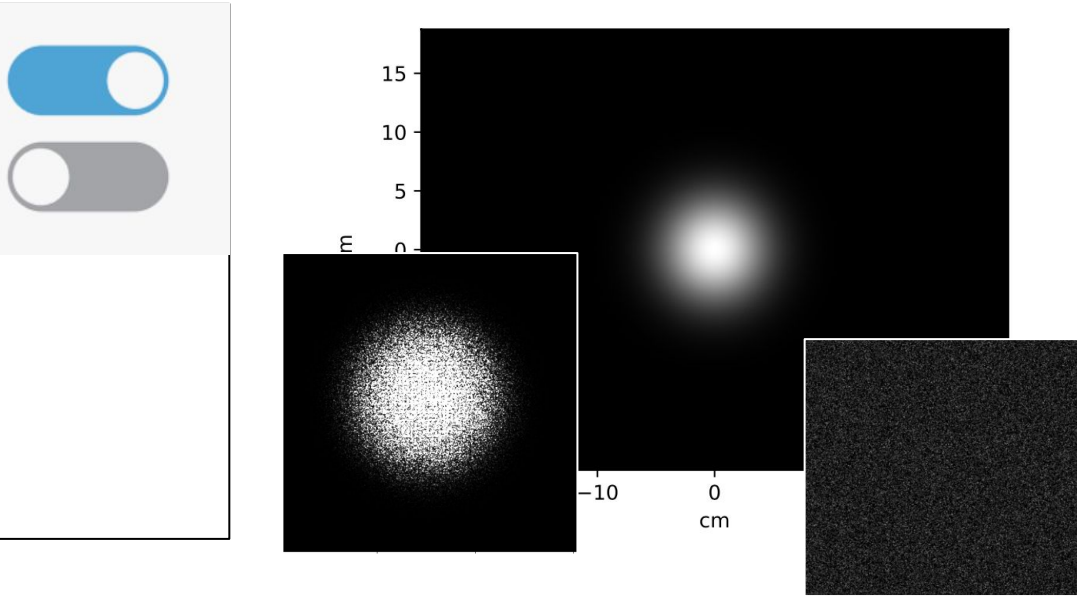


Centroid tracking will not work.

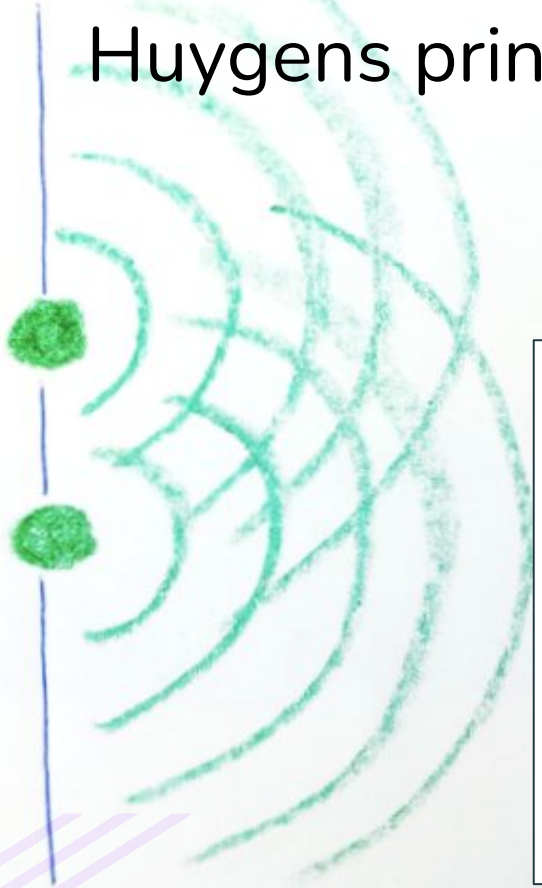
TOO MANY IRREGULARITIES.

Components of a Modular Simulation

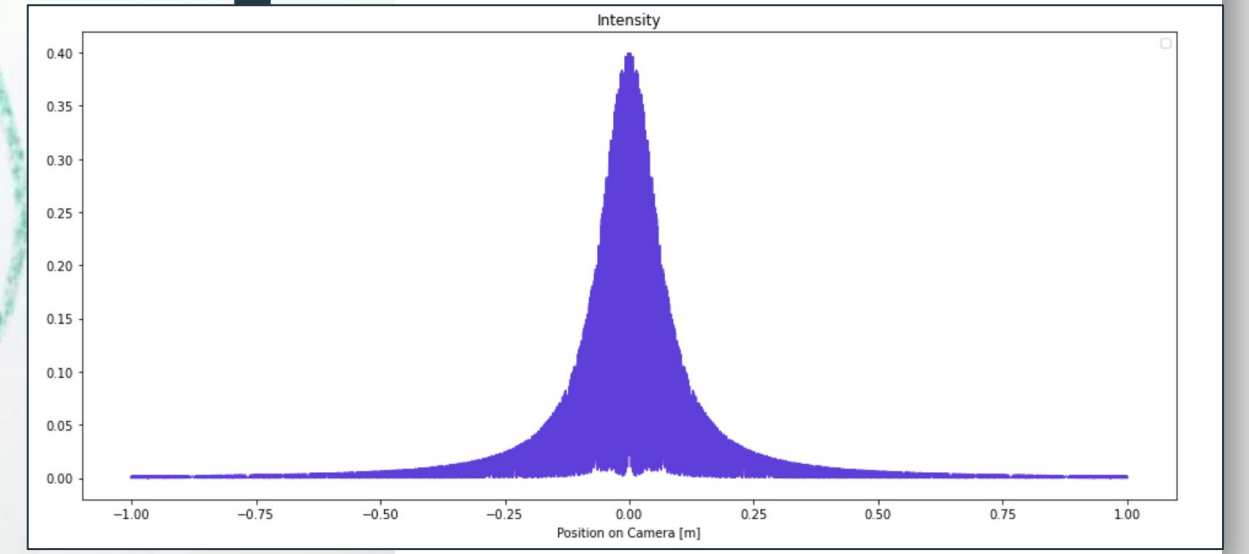
- Gaussian Beam
- Point defects
- Surface Roughness
- Saturation
- Shot Noise



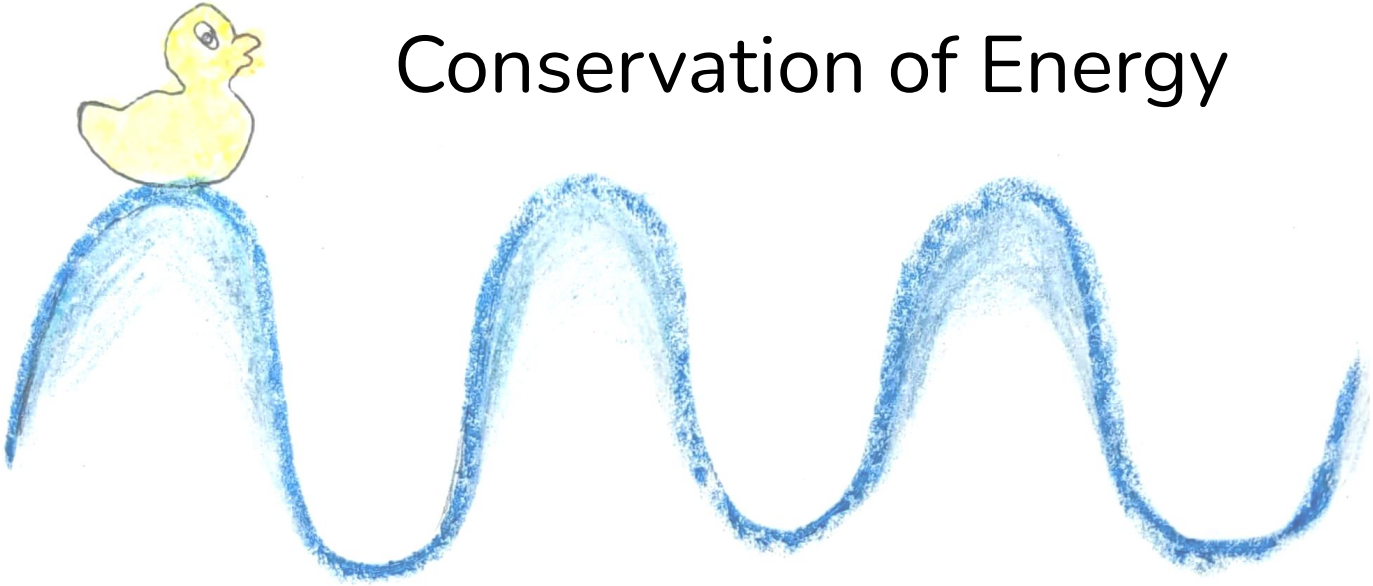
Point Defects; Huygens principle



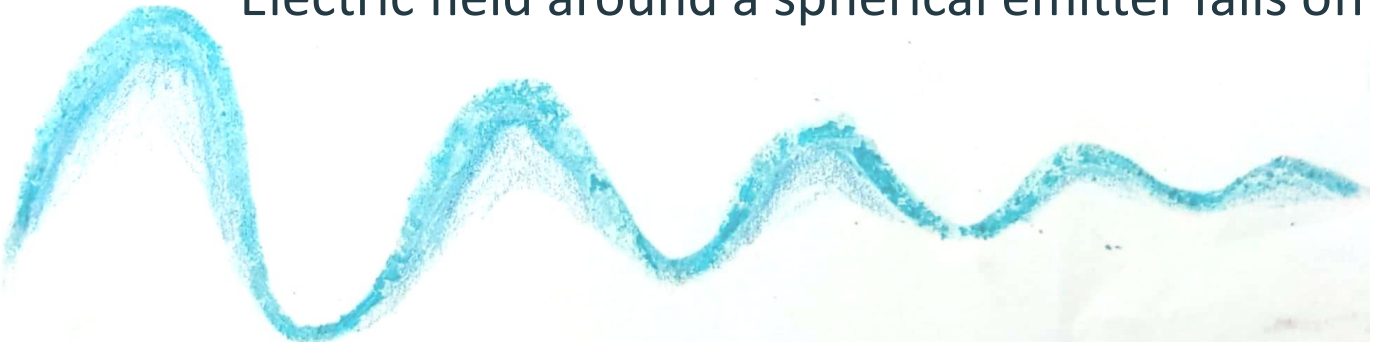
(This is a camera)



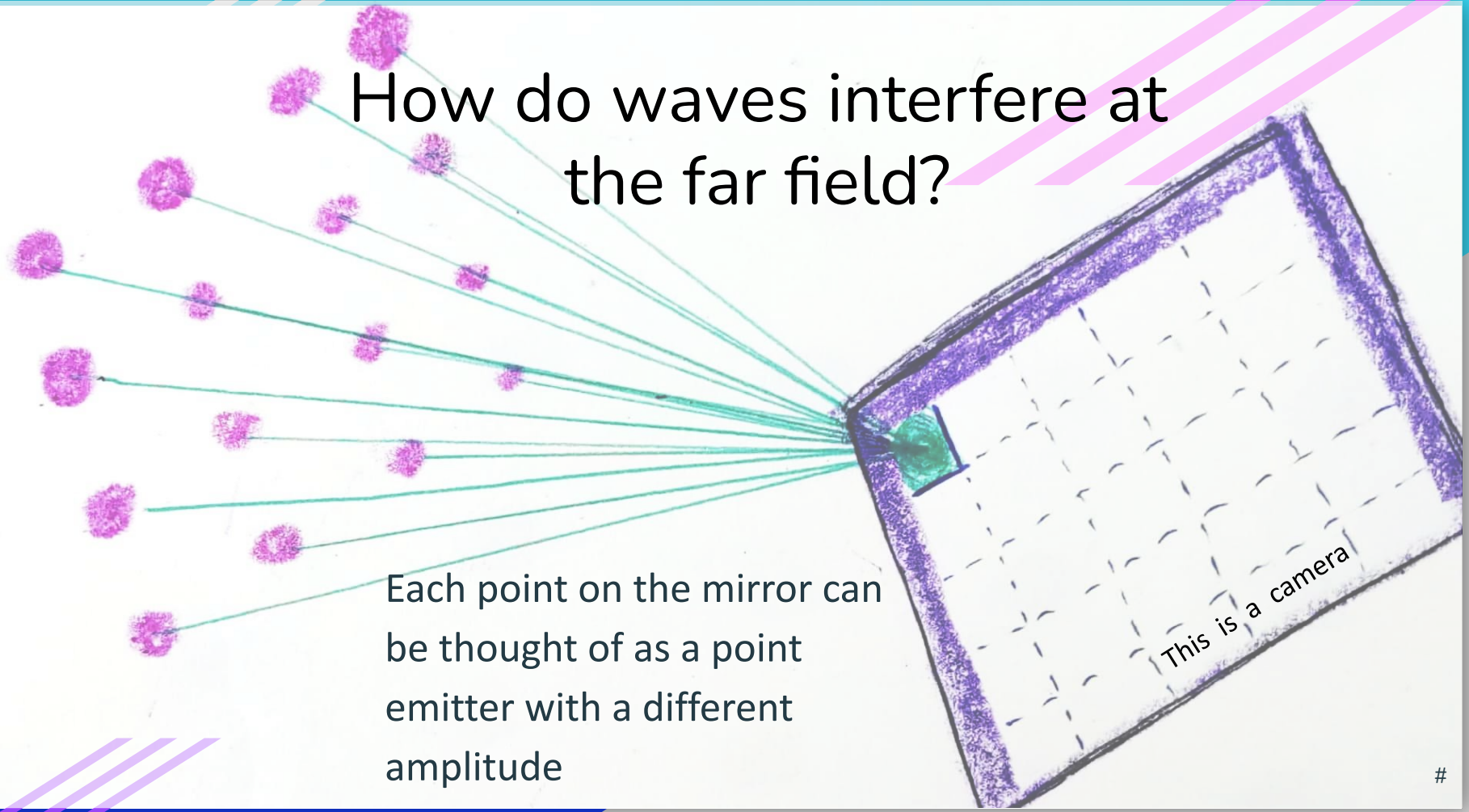
Conservation of Energy



Electric field around a spherical emitter falls off as 1/radius

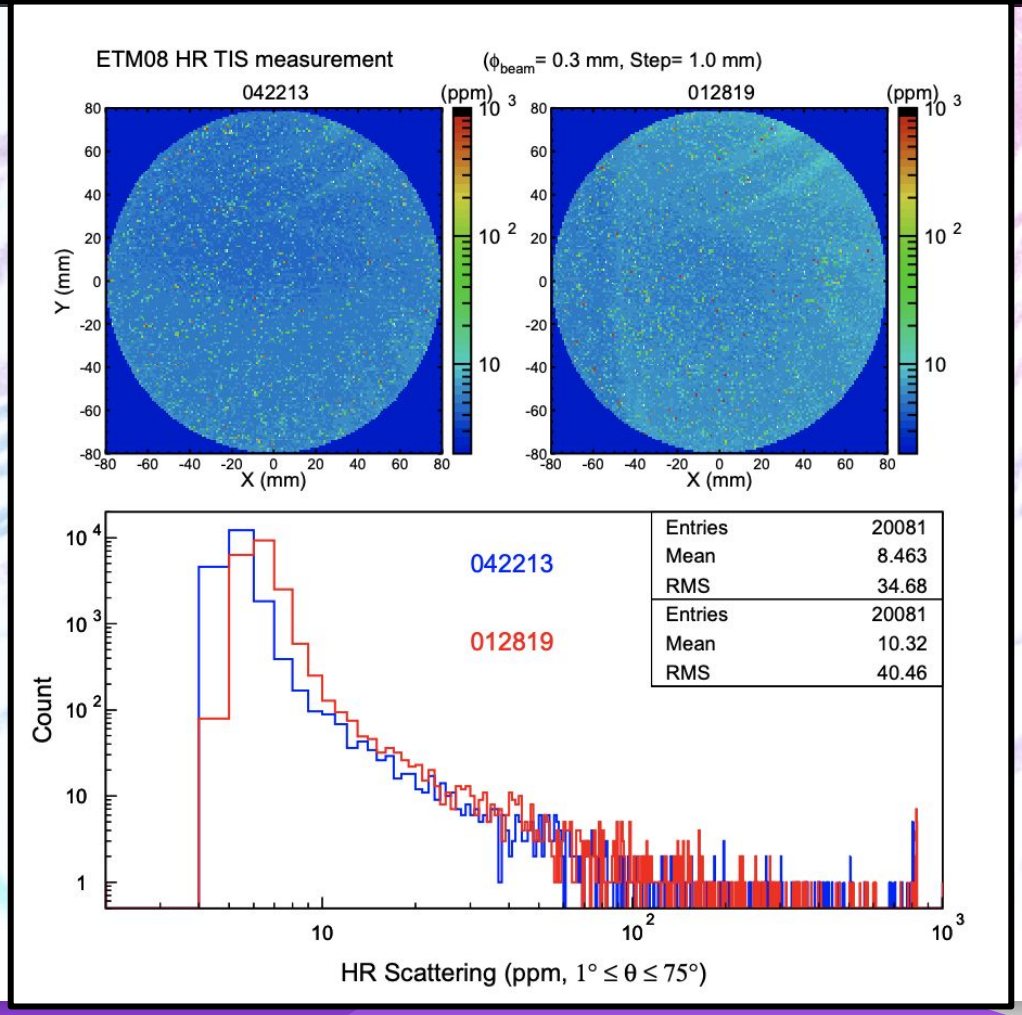


How do waves interfere at the far field?



Each point on the mirror can be thought of as a point emitter with a different amplitude

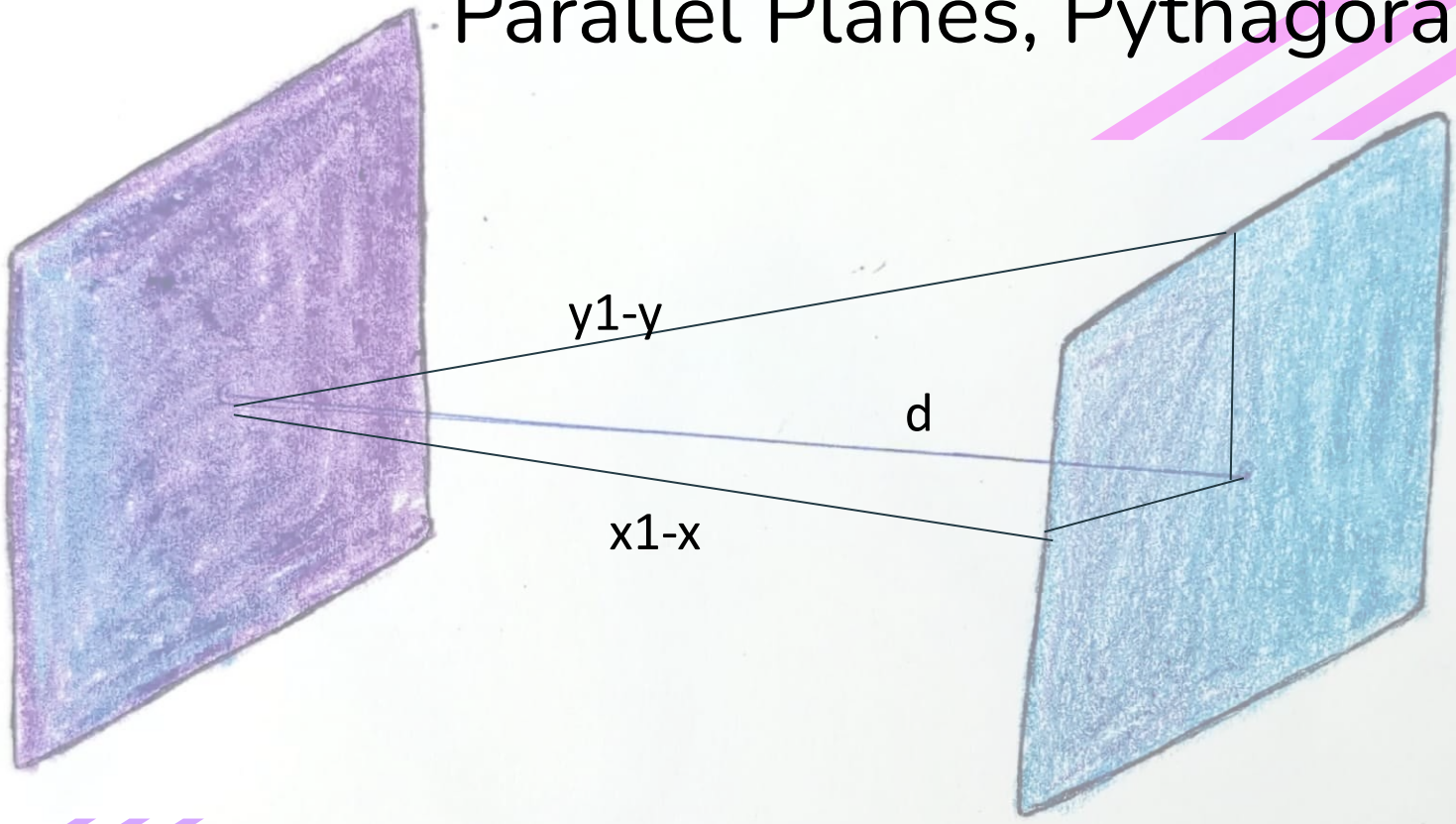
Amplitude of emitters



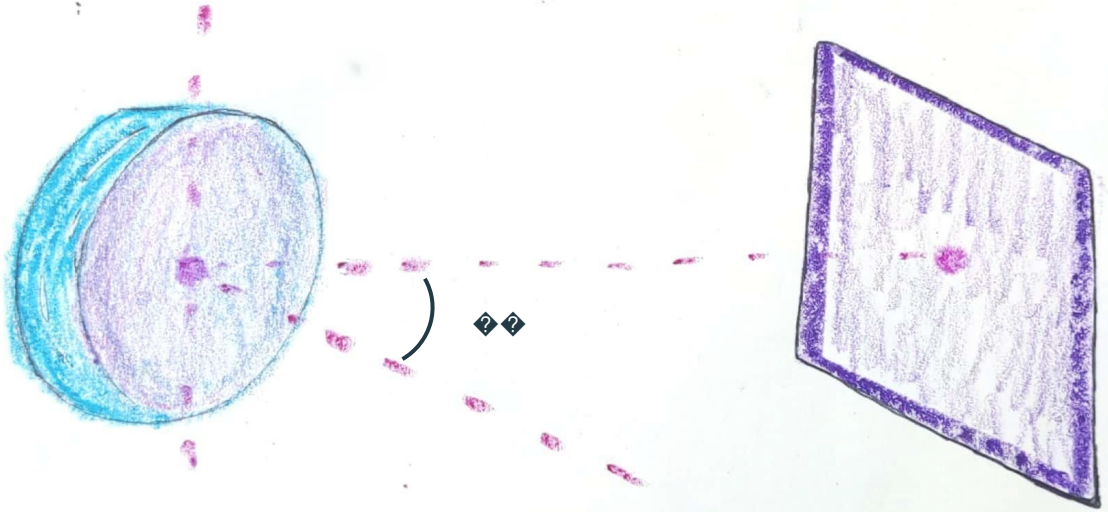
Dependent on Gaussian intensity and Total Integrated Scatter distribution.

Zhang et al. (2019)

Parallel Planes, Pythagoras

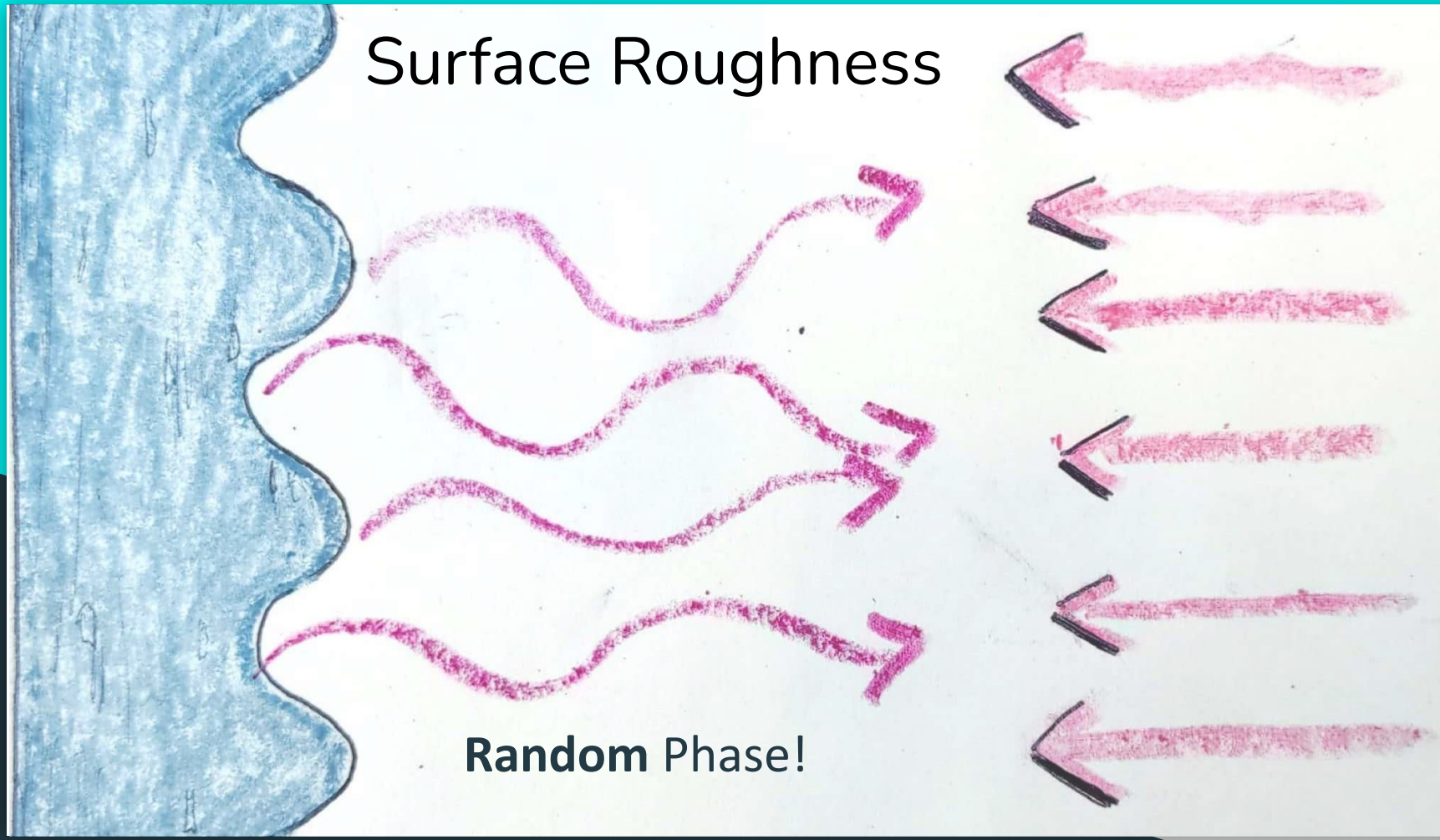


Camera Position and Orientation



Encoded in the radius

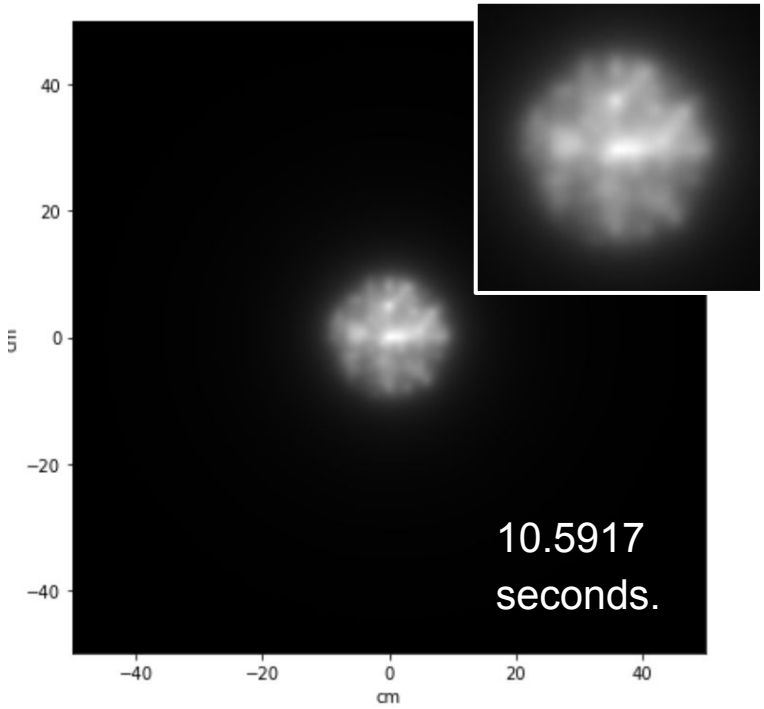
Surface Roughness



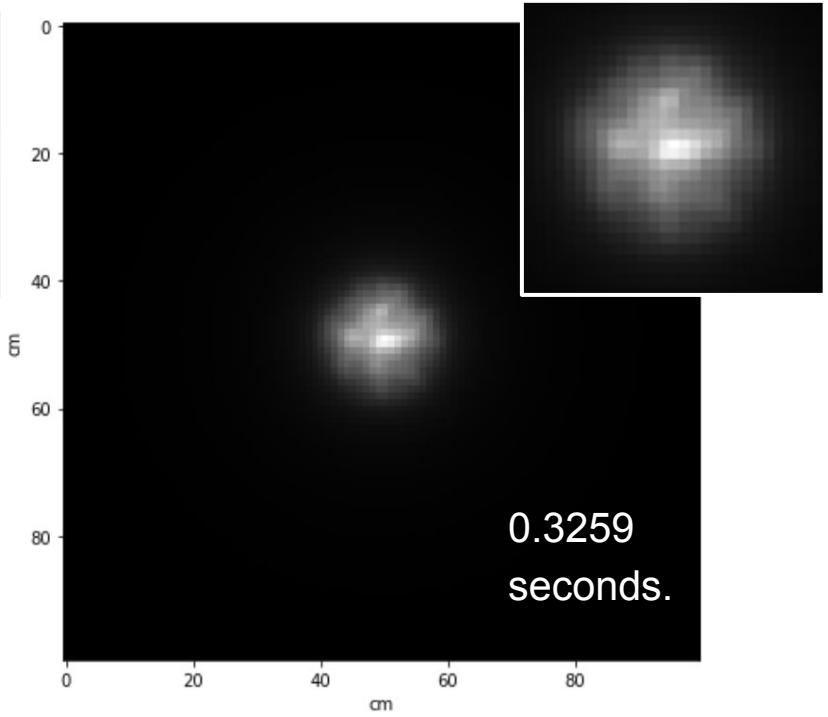
Random Phase!

Computational Efficiency

500 point scatterers 500px grid



500 point scatterers 100px grid



Moving pictures, moving forward, questions that arose

Can different models cooperate?

String things together and train the network

Layering effects

Do point scatterers change the polarization of the beam?

Acknowledgements:

The NSF and LIGO Lab for the opportunity to meet such lovely people.

My friends for their kindness, curiosity, ready humor and enthusiastic willingness to participate in the LIGOLYMPICS.

My mentors. And Derek!

Summary

- To find the beam: Convolutional Neural Networks
- Create modular simulation to generate huge amounts of representative data
- Modeling a mirror surface as an array of spherical point emitters
- Layering visual components